Impact of Planting Date on Sunflower Beetle (Coleoptera: Chrysomelidae) Infestation, Damage, and Parasitism in Cultivated Sunflower

LAURENCE D. CHARLET AND JANET J. KNODEL[1]

Northern Crop Science Laboratory, Agricultural Research Service, U.S. Department of Agriculture, Fargo, ND 58105–5677

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ABSTRACT The sunflower beetle, *Zygogramma exclamationis* (F.), is the major defoliating pest of sunflower (*Helianthus annuus* L.). Planting date was evaluated as a potential management tool in a variety of production regions throughout North Dakota from 1997 to 1999, for its impact on sunflower beetle population density of both adults and larvae, defoliation caused by both feeding stages, seed yield, oil content, and larval parasitism in cultivated sunflower. Results from this 3-yr study revealed that sunflower beetle adult and larval populations decreased as planting date was delayed. Delayed planting also reduced defoliation from adult and larval feeding, which is consistent with the lower numbers of the beetles present in the later seeded plots. Even a planting delay of only 1 wk was sufficient to significantly reduce feeding damage to the sunflower plant. Yield reduction caused by leaf destruction of the sunflower beetle adults and larvae was clearly evident in the first year of the study. The other component of sunflower yield, oil content, did not appear to be influenced by beetle feeding. The tachinid parasitoid, *Myiopharus macellus* (Rheinhard), appeared to be a significant mortality factor of sunflower beetle larvae at most locations regardless of the dates of planting, and was able to attack and parasitize the beetle at various larval densities. The results of this investigation showed the potential of delayed planting date as an effective integrated pest management tactic to reduce sunflower beetle adults, larvae, and their resulting defoliation. In addition, altering planting dates was compatible with biological control of the beetle, because delaying the planting date did not reduce the effectiveness of the parasitic fly, *M. macellus*, which attacks the sunflower beetle larvae.

KEY WORDS sunflower beetle, *Zygogramma exclamationis,* biological control, cultural control, *Myiopharus macellus*

THE SUNFLOWER BEETLE, *Zygogramma exclamationis* (F.), is the major defoliating pest of sunflower (*Helianthus annuus* L.) in the northern plains of the United States and Canada. Adults overwinter in the soil and emerge the following May to begin feeding. After mating, females deposit eggs singly on the sunflower stem or underside of leaves. Larvae develop through four instars and are present in the field for approximately 6 wk. Mature larvae enter the soil to pupate in July and the next generation of adults emerge and are present on the plants for approximately 2 wk before reentering the soil to overwinter in mid-August. Both the adult and larval stages consume the leaf tissue and when beetle populations are high, damage can result in yield loss (Westdal 1975, Rogers 1977, Charlet 1992, Charlet et al. 1997).

Although the use of chemicals has been effective in managing sunflower beetles and preventing yield loss in cultivated sunflower, the frequent application of pesticides can potentially risk the development of insecticide resistance. Predators and parasitoids attack all stages of the sunflower beetle and are a significant factor in maintaining the pest at densities below the economic threshold (Westdal 1975, Charlet 1992, Knodel et al. 2000). The tachinid fly, *Myiopharus macellus* (Rheinhard), is an important natural enemy of *Z. exclamationis* parasitizing up to 50% of larvae (Charlet 1992). The parasitoid larviposits first instars into sunflower beetle larvae and maggots complete development after the fourth-instar beetles enter the soil to pupate. The fly emerges as an adult in late summer at approximately the same time as the sunflower beetle adults emerge. The overwintering habits of the parasitoid are unknown (Neill 1982, Charlet 1992).

Cultural control, as part of an integrated pest management (IPM) program, can be used to modify the cropping environment to reduce pest densities and enhance or at least not interfere with the activity of

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[1] North Central Research Extension Center, North Dakota State University, 5400 Highway 83 S, Minot, ND 58701–7645.

Table 1. Leaf defoliation resulting from sunflower beetle adult and larval feeding and percentage parasitization of larvae in sunflower planted at three different dates, Fargo, 1997

Year	Location	Planting date	% Defoliation $\bar{x} \pm$ SE	% Larval parasitization $\bar{x} \pm$ SE
1997	Fargo	15 May	9.0 ± 0.6a	40.7 ± 0.6a
		27 May	10.5 ± 0.8a	55.3 ± 0.8a
		6 June	2.6 ± 0.4b	50.7 ± 0.7a

Means followed by the same letter within the same column are not significantly different ($P < 0.05$) using LSD. Percentages transformed using arc sine.

natural enemies (Letourneau and Altieri 1999). Manipulating planting dates effectively reduced damage from a number of sunflower pests, including the sunflower stem weevil (*Cylindrocopturus adspersus* (LeConte)), the banded sunflower moth (*Cochylis hospes* Walsingham), and the red sunflower seed weevil (*Smicronyx fulvus* LeConte) without appreciable loss in seed weight or oil content (Oseto et al. 1982, 1987, 1989; Rogers et al. 1983, Charlet and Busacca 1986).

Our goal was to determine whether altering planting dates could reduce sunflower beetle feeding and damage in cultivated sunflower in various production regions throughout North Dakota from 1997 to 1999. To evaluate the impact of planting date, the following parameters were determined: population density of both adults and larvae, defoliation caused by both feeding stages, seed yield, oil content, and larval parasitism.

Materials and Methods

Trials were conducted at the North Dakota State University (NDSU) campus plots in Fargo, ND, 1997–1999. During 1998 and 1999, three additional North Dakota locations were selected for the trials: Prosper (NDSU Research Site) in east central North Dakota; Carrington (NDSU Research Extension Center field plots) in south central North Dakota; and Minot (NDSU Research Extension Center field plots) in north central North Dakota. Plots were seeded at three intervals to coincide with an early (mid May), typical (late May), and late (early June) planting date (Tables 1–3). The planting dates in 1997 were 15 and 27 May and 6 June. Because of wet field conditions in 1998, planting was delayed at the Prosper and Minot sites. The planting dates were as follows: Fargo (20 and 27 May and 8 June), Prosper (20 and 26 May and 8 June), Carrington (15 and 28 May and 12 June), and Minot (22 and 29 May and 8 June). In 1999, wet field conditions delayed planting at the Prosper and Minot locations. The planting dates in 1999 were as follows: Fargo (19 and 25 May and 7 June), Prosper (27 May and 8 and 16 June), Carrington (20 and 27 May and 8 June), and Minot (25 May and 8 and 14 June). The average temperature and total precipitation from 1997 to 1999 for the period May through August at the different locations was as follows: Fargo (1997: 18.3°C and 291.3 mm; 1998: 19.4°C and 437.4 mm; 1999: 19.1°C and 302.8 mm); Prosper (1998: 18.9°C and 346.7 mm; 1999: 18.3°C and 281.9 mm); Carrington (1998: 17.7°C and 158.5 mm; 1999: 17.3°C and 384.8 mm); and Minot (1998: 17.9°C and 286.0 mm; 1999: 17.3°C and 326.7 mm).

Plots were seeded in 1997 with sunflower hybrid '894' and in 1998 and 1999 with Cargill NuSun hybrid 290NL using a randomized block design with three (1997) or four replicates (1998 and 1999). The change in hybrids was made to conform to a oil type more frequently seeded by producers. Plots were either 8 rows (1997) or 12 rows (1998 and 1999) by 7 m with rows 76 cm apart and plants spaced 30.5 cm within rows. A preplant application of herbicide was used, but no other chemicals were applied throughout the trials.

Sunflower beetle adults and larvae were counted on five plants at five random locations within each plot (based on time and resources available for sampling) beginning in mid-June, when the latest planting was emerging from the soil [VE stage (Schneiter and Miller 1981)]. Sampling continued weekly until late July or early August when insect feeding was finished.

Table 2. Leaf defoliation resulting from sunflower beetle adult and larval feeding, yield, percentage of oil content, and percentage parasitization of larvae in sunflower planted at three different dates in four locations in North Dakota, 1998

Location	Planting date	% Defoliation $\bar{x} \pm$ SE	Yield (gm/head) $\bar{x} \pm$ SE	% Oil $\bar{x} \pm$ SE	% Larval parasitization $\bar{x} \pm$ SE
Fargo	20 May	13.1 ± 1.9a	62.2 ± 3.8a	49.6 ± 0.4a	45.0 ± 6.4a
	27 May	6.1 ± 0.7b	90.0 ± 6.1b	47.3 ± 0.6b	45.8 ± 3.8a
	8 June	1.3 ± 0.2c	80.6 ± 4.0b	47.3 ± 0.4b	59.3 ± 2.4a
Prosper	20 May	4.8 ± 0.4a	89.0 ± 4.4a	43.9 ± 0.6a	32.8 ± 8.0a
	26 May	3.7 ± 0.5b	80.0 ± 5.6a	42.7 ± 0.8a	42.5 ± 7.3a
	8 June	1.9 ± 0.2c	115.9 ± 6.0b	46.5 ± 0.5b	46.0 ± 3.4a
Carrington	15 May	11.4 ± 1.5a	44.4 ± 2.9a	44.8 ± 0.4a	3.0 ± 0.6a
	28 May	5.0 ± 1.2b	57.0 ± 3.4b	41.5 ± 0.5b	0.5 ± 0.5b
	12 June	0.7 ± 0.2c	55.8 ± 2.8b	40.4 ± 0.5b	0.5 ± 0.5b
Minot	22 May	8.5 ± 0.8a	72.7 ± 5.2a	46.8 ± 0.4a	12.0 ± 2.2a
	29 May	8.0 ± 1.0a	78.2 ± 5.0a	47.3 ± 0.6a	15.0 ± 3.4a
	8 June	5.5 ± 0.3b	77.2 ± 4.7a	47.4 ± 0.7a	8.5 ± 2.6a

Means followed by the same letter within the same column by location are not significantly different ($P < 0.05$) using LSD. Percentages transformed using arc sine.

Table 3. Leaf defoliation resulting from sunflower beetle adult and larval feeding, yield, percentage of oil content, and percentage parasitization of larvae in sunflower planted at three different dates in four locations in North Dakota, 1999

Location	Planting date	% Defoliation $\bar{x} \pm$ SE	Yield (gm/head) $\bar{x} \pm$ SE	% Oil $\bar{x} \pm$ SE	% Larval parasitization $\bar{x} \pm$ SE
Fargo	19 May	6.6 ± 0.4a	93.2 ± 4.3a	50.3 ± 0.4a	19.6 ± 12.2a
	25 May	5.2 ± 0.4b	100.3 ± 5.2a	48.1 ± 0.8b	53.4 ± 3.4b
	7 June	3.1 ± 0.4c	97.4 ± 4.3a	46.5 ± 0.7b	45.1 ± 7.1ab
Prosper	27 May	2.7 ± 0.2a	82.9 ± 4.3a	43.9 ± 0.7a	54.3 ± 4.3a
	8 June	1.9 ± 0.2b	72.8 ± 3.7a	44.3 ± 0.7a	53.2 ± 2.9a
	16 June	1.3 ± 0.1c	79.3 ± 4.4a	43.1 ± 0.6a	58.6 ± 6.2a
Carrington	20 May	5.7 ± 0.3a	75.5 ± 2.6a	46.8 ± 0.4a	31.3 ± 1.6a
	27 May	3.8 ± 0.4b	68.2 ± 2.7a	44.4 ± 0.6b	28.1 ± 4.7a
	8 June	1.8 ± 0.2c	56.7 ± 2.6b	46.6 ± 0.4a	45.0 ± 2.7b
Minot	25 May	7.7 ± 0.5a	93.9 ± 5.6a	45.0 ± 0.4a	43.7 ± 8.3a
	8 June	2.3 ± 0.3b	63.7 ± 2.9b	34.9 ± 0.7b	60.0 ± 2.1a
	14 June	2.5 ± 0.4b	47.5 ± 5.5c	30.0 ± 0.9c	52.0 ± 1.2a

Means followed by the same letter within the same column by location are not significantly different ($P < 0.05$) using LSD. Percentages transformed using arc sine.

In late July, ≈50 mature (fourth-stage) larvae were collected from each plot and dissected in the laboratory to determine the percentage parasitized by the internal larval parasitoid, *M. macellus.*

Defoliation on individual plants was visually estimated using charts showing a range of damage of defoliated leaves determined with a leaf area meter (Li-Cor, Inc., Lincoln, NE). Percent defoliation was calculated by averaging the defoliation on the leaves of the upper half of five sunflower plants at 10 random locations within each plot. Defoliation estimates were made on 30 July 1997, between 7 and 14 August 1998, and between 11 and 19 August 1999, when all beetle feeding was complete. At this time, the majority of larvae were fourth instars and had moved into the soil to pupate. In 1998 and 1999, 10 heads were bagged in each plot when plants had completed flowering (R7–8 stage) to prevent bird damage. Heads were harvested after physiological maturity (R9 stage) from late September to early October. Heads were dried until seeds were below 10% moisture, threshed, cleaned, and weight of seeds per head determined. Samples of seeds were collected and the percent of oil computed using a nuclear magnetic resonance analyzer.

The analysis of variance option of the GLM procedure was used to compare defoliation, yield, oil content, and rates of parasitization among the three planting dates for each location and study year. Significantly different means were separated using least significant difference (LSD) ($P < 0.05$). Percentages were transformed using arc sine before analysis (SAS Institute 1990).

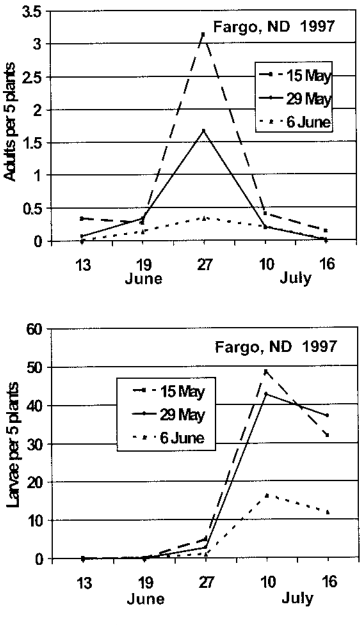

Fig. 1. Sunflower beetle population densities based on the mean number of adults and larvae per five plants at three different planting dates, Fargo, ND, 1997

Results

Adult and Larval Densities. Sampling in 1997 study plots at Fargo, ND, showed adult numbers highest in late June, with densities consistently lower as planting date was delayed (Fig. 1). Adult populations in plots seeded on the first date (15 May) peaked at three adults per five plants, below the reported economic threshold of 1–2 sunflower beetle adults per plant (5–10 per five plants) (McBride et al. 1994, Knodel et al. 2000). Densities of sunflower beetle larvae were greatest in early July in all plantings with numbers similar in the first two plantings but at levels much higher than in the last planting (Fig. 1). Larval numbers approached, but did not reach, the larval economic threshold of 10–15 larvae per plant (50–75 per five plants) in any of the three planting dates (McBride et al. 1994, Knodel et al. 2000).

In 1998 at the Fargo site, adult numbers were greatest in the first planting (average of 0.8 per five plants for the sampling period), except for one sampling time, but none exceeded the economic threshold (Fig. 2). Densities of adults (peak of 2.5 per five plants) at Prosper were greatest in the first planting compared

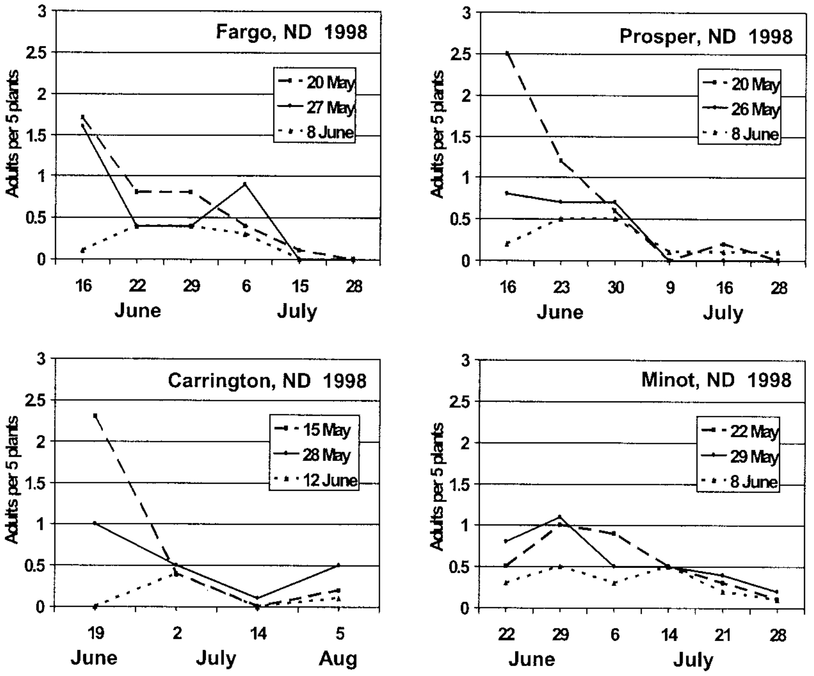

Fig. 2. Sunflower beetle population densities based on the mean number of adults per five plants at three different planting dates at Fargo, Prosper, Carrington, and Minot, ND, 1998

with the other two plantings for most of the sampling periods. Initial adult counts at Carrington (Fig. 2) again showed that densities decreased with later plantings. The results at the Minot location were not as consistent as the other locations, but the third planting did have lower densities of adults than the first two plantings. Among the four locations studied, peak adult density during the period of sampling occurred in mid-June at Fargo, Prosper, and Carrington, but was shifted to the end of June at Minot (Fig. 2). This might be because of a later emergence of adults because this site was the most northerly of the four study locations and average soil temperature in June was 16.7°C compared with 17.8–18.3°C for the other three sites.

The density of larvae at Fargo in 1998 was the largest of all four locations, with an average during all the sampling dates in first planting of 40 larvae per five plants (Fig. 3). The greatest population of larvae occurred in the first planting and decreased as planting date was delayed. Larval numbers were highest in early July for all three plantings. Larval densities in the first planting peaked at 73 larvae per five plants, exceeding the larval economic threshold. Larval densities at both Prosper and Carrington tended to decline as planting was delayed with numbers in the second and third plantings less than in the first planting. Larval population at Carrington did reach the economic threshold in the first planting, when plants were at the 12–14 leaf stage. Although the number of larvae among the different plantings at Minot was not as consistent as the other locations (as was the case with the adults), the plots planted last did have the least beetle density. Peak populations of larvae occurred between 2–9 July, except for Minot, which had the greatest density in mid-July.

At Fargo, adult numbers in 1999 were greatest in the first planting, peaking on 1 July (Fig. 4). Overall, the populations occurring at all three planting dates were lower than in 1998. Densities of adults at Prosper were greatest in the first planting for most of the sampling times (Fig. 4). Adult numbers in Carrington were higher than those in Fargo even though these two locations had similar planting dates (Fig. 4). Peak densities of adults in the first planting also were somewhat larger than at Prosper and Minot, but this date actually corresponded to the second planting at the latter two locations. Counts again showed that densities decreased with later plantings. Counts of adults in Minot in 1999 (Fig. 4) showed that the second and third plantings did have much lower densities of adults than the first planting. Among the four locations, peak adult density occurred in early July at Fargo, Prosper, and Minot, but was shifted 1 wk earlier at Carrington. Average soil temperatures in June, which impact emergence of the beetle, were 1–2°C higher in Carrington than in Prosper or Minot.

Overall, numbers of sunflower beetle larvae at all locations were lower in 1999 than in 1998. The greatest population of larvae at the Fargo site in 1999 occurred in the first planting and decreased as planting date was delayed (Fig. 5). Larval numbers peaked in early July for the first two plantings. Larval densities in the first

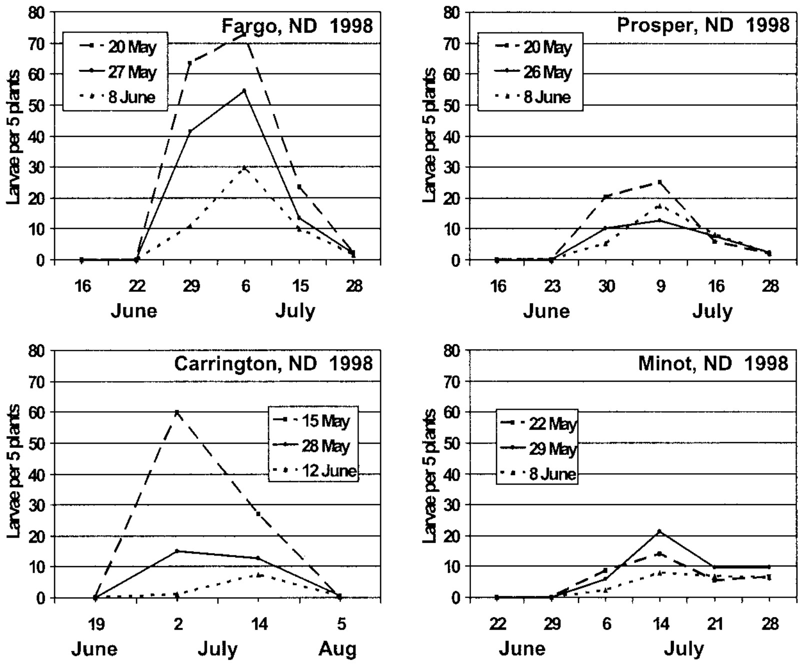

Fig. 3. Sunflower beetle population densities based on the mean number of larvae per five plants at three different planting dates at Fargo, Prosper, Carrington, and Minot, ND, 1998

planting peaked at two larvae per five plants, far below the economic threshold of 10–15 larvae per plant. Larval densities declined at Prosper as planting was delayed with numbers in the second planting less than one half that in the first planting (Fig. 5). The third planting at Prosper had almost no larvae, because it was planted later than any of the other sites in the study. Populations of larvae in the first planting at

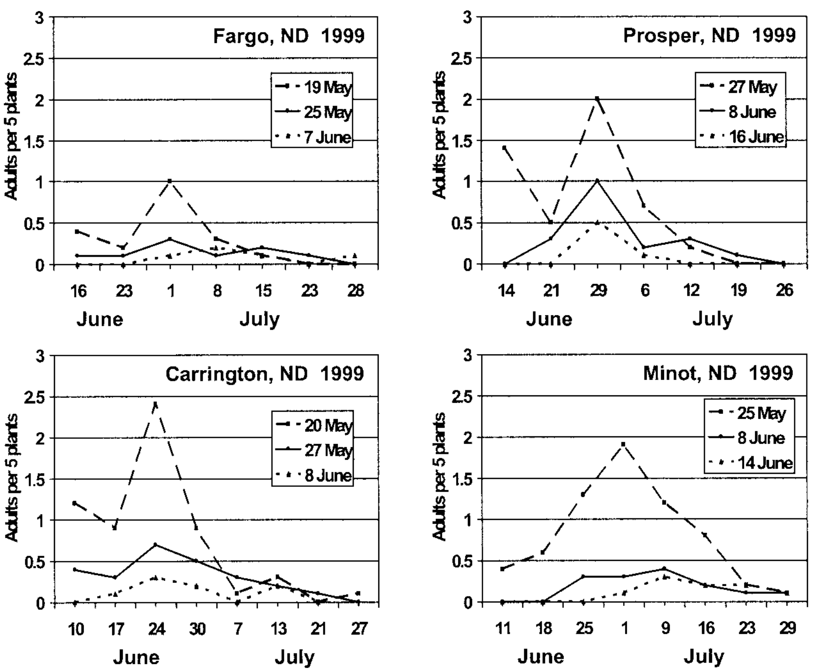

Fig. 4. Sunflower beetle population densities based on the mean number of adults per five plants at three different planting dates at Fargo, Prosper, Carrington, and Minot, ND, 1999

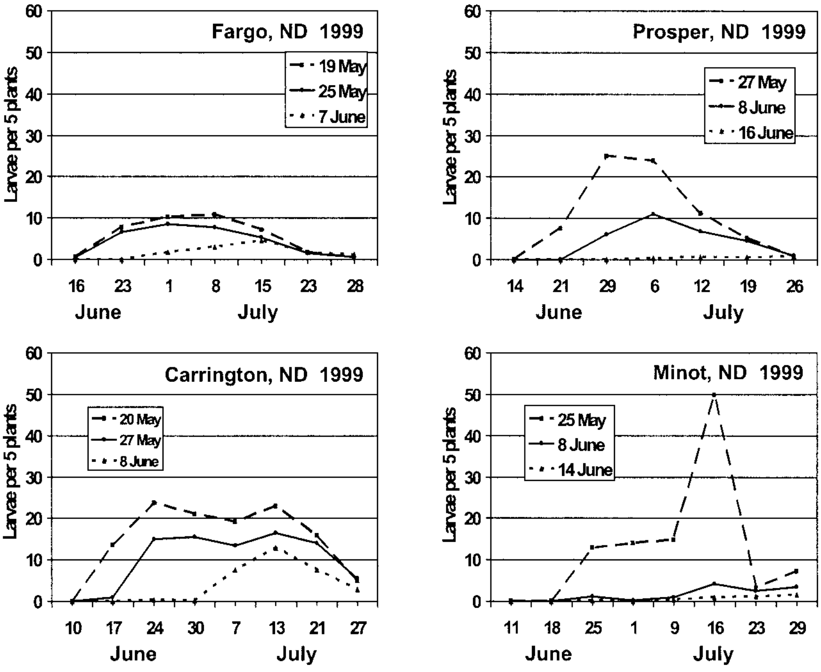

Fig. 5. Sunflower beetle population densities based on the mean number of larvae per five plants at three different planting dates at Fargo, Prosper, Carrington, and Minot, ND, 1999.

Carrington also were greater compared with the second and third plantings (Fig. 5). Larval numbers at Minot (Fig. 5) were much higher in the first planting than the second or third plantings, which was again consistent with the other three study locations. Peak populations of larvae occurred from late June to mid-July at all locations.

Defoliation. In 1997, defoliation of plants resulting from combined feeding of adults and larvae was significantly lower at the third planting compared with the first two seeding dates. These findings were consistent with comparisons of adult and larval densities within the study plots showing lower numbers resulted in decreased leaf consumption as date of planting was delayed (Table 1).

The comparison of percent defoliation in 1998 caused by combined adult and larval feeding revealed that at all locations damage decreased as planting date was delayed (Table 2). At Fargo, Prosper, and Carrington, there was a significant difference among all planting dates. At the three locations at which the first two plantings were only spaced one week apart, there was still a significant decrease in defoliation between those dates for two of the sites (Fargo and Prosper) (Table 2). At all four locations defoliation was significantly lowest at the third planting.

The comparison of percent defoliation in 1999, as in 1998, showed that at all locations studied, feeding damage decreased as planting date was delayed (Table 3). This result is consistent with lower populations of beetle adults and larvae in the later plantings. Minot was the only site at which there was no significant difference between all three plantings because of lower levels of beetles. At Fargo and Carrington, where the first two plantings were only spaced about 1 wk apart, there was still a significant decrease in defoliation between those dates (Table 3).

Yield and Oil Content. Seed yield comparisons from the different planting dates in 1998, although not as consistent as the defoliation data, did show that at most locations seed weight per head were less at the first planting compared with the June planting date (Table 2). There were no differences in yield among plantings at Minot. However, this was probably because of the lower densities of the sunflower beetles and consequently the reduced defoliation of the plants.

Oil content varied among locations and planting dates in 1998 (Table 2). Oil content was greatest at the first planting in Fargo and Carrington but was highest at the third planting in Prosper. There were no differences among the three plantings at Minot. Overall, the analysis revealed that the seed from the first planting, where defoliation was greatest, had the highest levels of oil, suggesting that the response was probably a result of factors other than plant feeding damage caused by the beetle.

Comparisons of seed yield from the different planting dates in 1999 were not as consistent as the defoliation data (Table 3). There were no differences in yield among planting dates at either Fargo or Prosper. At the other locations, the yield was actually highest at the first planting when beetle densities were greatest. However, because of the lower densities of the sunflower beetles in 1999 than in 1998, and consequently the reduced defoliation of the plants, the damage may not have been enough to impact the yield.

Oil content varied in 1999 among locations and planting dates (Table 3). Oil content was greatest at the first planting in Fargo and Minot and equal for all planting dates at Prosper. At Carrington, the oil level was lower at the second planting than either the first or third plantings. As in the case of yield, the response was not caused by beetle feeding but was most likely a result of environmental factors, such as temperature, moisture levels, or soil fertility.

Parasitism. In 1997, 40–50% of dissected sunflower beetle larvae were parasitized by the tachinid, *M. macellus*, among the three plantings (Table 1). Although larval densities were lower in the third planting (Fig. 1), there was no significant difference in parasitism of larvae.

Parasitism of sunflower beetle larvae in 1998 by *M. macellus* was generally similar among the three plantings (Table 2). Except for Carrington, there was no significant difference among plantings within sites, even though beetle densities were different (Figs. 2 and 3). Parasitism was greatest at Fargo and Prosper (33–60% of larvae attacked) and lowest at Carrington (1–3%).

Parasitism of sunflower beetle larvae by *M. macellus* in 1999 was similar among the three plantings at two of the four sites (Table 3). With the exception of Fargo and Carrington, there was no significant difference among planting dates within sites. The lower rate of parasitization of larvae in the first planting at Fargo was probably a result of the lower number of larvae available when they were collected from the field for dissection. Parasitization rates were higher than in 1998 and all sites had at least one planting date where parasitization was 45–50%.

Discussion

Results from this 3-yr study revealed that sunflower beetle adult and larval populations decreased as planting date was delayed. The data were consistent even though planting dates were not the same at all locations, rainfall varied by year and location, and average temperatures during the season were lower in the two more northerly sites (Carrington and Minot). Earlier studies showed that sunflower beetle adults emergence begins in early May with peak adult density on plants in mid-June (Charlet 1991, 1992). Thus, plants in plots that had emerged and were actively growing would be selected for feeding and egg laying. Once hatched, larvae remain on the plants until development is completed (Neill 1982, Charlet 1992). An investigation of the effect of planting date on the sunflower stem weevil in North Dakota showed a decline in densities of both adults and larvae in the later planted sunflowers (Oseto et al. 1982). In Texas, a study by Rogers and Jones (1979) also revealed that delaying planting date resulted in reduced stem weevil larval infestations in sunflower. Planting date investigations with another important sunflower pest, the banded sunflower moth, also noted that there were lower numbers of larvae present in later planted sunflower as shown by the reduced seed damage present (Charlet and Busacca 1986, Oseto et al. 1989).

Delayed planting also reduced defoliation of plants caused by the feeding of both sunflower beetle adults and larvae, which is consistent with the lower numbers of the beetles present in the later seeded plots. Even a delay of only 1 wk was enough of an interval in some instances to result in a significant reduction in feeding damage to the sunflower plant. The impact of defoliation on the growth and development of the sunflower plant is dependent on the stage in which the leaf loss occurs. Hail simulation studies on sunflower showed that the reproductive stages R1 through R4 are the most sensitive to defoliation (Schneiter et al. 1987). However, these investigations were based on removal of leaves at specific plant stages. Feeding by the sunflower beetle is continuous and during part of the life cycle both stages consume leaf tissue at the same time. Also, larval feeding extends into sunflower's early reproductive stages (Charlet 1992).

Yield reduction caused by the leaf destruction of the sunflower beetle adults and larvae was clearly evident in the first year of the study. Earlier studies of defoliation conducted to determine the impact of hail clearly showed that sunflower yield decreased with loss of leaf tissue, although sunflower could sustain up to a 25% defoliation without a reduction in seed yield (Schneiter et al. 1987, Blamey et al. 1997). It is thus likely that lower densities of beetles and consequently reduced defoliation, at some of the locations and planting dates in 1999, resulted in an inconsistent impact on yield. Similar results were seen in a planting date study with the banded sunflower moth where damage decreased with planting date but corresponding yield increases were not always detected (Oseto et al. 1989). The other component of sunflower yield, the oil content, did not appear to be influenced by beetle feeding at the different plantings. Connor and Hall (1997) noted that studies have shown that a variety of environmental factors including temperature, water stress, and nitrogen levels can have an effect on the oil quantity caused, in part, by a larger pericarp to kernel ratio in the sunflower seed.

The parasitoid, *M. macellus*, appeared to be a consistent, significant mortality factor of sunflower beetle larvae at most locations over all dates of planting. Thus, altering planting date is compatible with sunflower beetle biological control. The factors responsible for the low rates of parasitism at Carrington and Minot in 1998 are not clear because parasitization levels were comparable to the other locations the next year. Results from all three years revealed that the parasitoid was able to attack and parasitize the beetle at varied larval densities. This is likely because, as earlier studies revealed, *M. macellus* actively searched and larviposited in sunflower beetles over a 4-wk period from mid-June to mid-July. The parasitoid showed a strong functional response to larval populations of the beetle, with a consistent rate of parasitism even as densities of the beetle increased (Charlet 1992). Charlet (2001) also noted that planting date did not negatively impact the parasitization rates of the two most abundant parasitoids of the banded sunflower moth.

The results of this investigation showed the potential of planting date as an effective nonchemical management strategy to reduce numbers of sunflower beetle adults and larvae and the resulting defoliation, and to thereby potentially prevent yield loss in cultivated sunflower. In addition, this IPM tactic is compatible with biological control, another IPM strategy, because delaying the planting date did not reduce the effectiveness of the parasitic fly that attacks the sunflower beetle larvae.

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